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CONTENTS

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THE PRACTICAL CLASSIFICATION OF SOILS

Relation of the Soil to Agricultural Practise.—The comprehensive study of agricultural questions which has arisen in recent years has revealed the necessity for accurate information on the character and distribution of soil conditions. It is being more clearly recognized how fundamentally the soil enters into all questions of agricultural betterment, both scientific and practical. Not only does the intelligent management of the soil rest upon a proper appreciation of the inherent physical, chemical and biological variations in soils in different parts of the country, but the suitability of these to different crops, the adustment of the crops which can best be produced to the business organization of the farm, its size, equipment, money product, transportation and market facilities, and the social life of the community are involved. The application of the results of the investigation of the institutions for agricultural research—the experiment stations, the colleges of agriculture and the federal and state departments of agriculture—must take account first of all of soil conditions. Types and varieties of crops, methods of culture, tillage, drainage, irrigation and fertilization give better results upon some types of soil than upon others. Those which are well suited to one soil may be a total failure upon some other soil. The experiment stations have often confined their study to one or two types of soil on the central institution farm. It is only within very recent years that the importance of carrying on investigations at substations, upon the several typical soil

formations which may exist in their territory, has been recognized. In all these and many other even larger questions a knowledge of the variety and distribution of the soils of a territory is of prime importance.

Principles of Classification.—The study of any group of facts or phenomena involves an understanding of the properties in which they may differ, and the systematic representation of these differences requires that the properties of importance be arranged and classified with reference to some controlling interest. Soil is no exception to this general rule, but the application of these principles in the field description of soils in a practical way and from the agricultural point of view presents many and complicated problems.

Definition of Soil.—In the discussion of the classification of soils, the soil should be viewed very broadly so as to include any portion of the earth's surface capable of producing plants. It includes thin, stony material as well as that of great depth and friability. It includes desert regions as well as humid regions. It includes the material as deep as any influence is exerted upon plants growing on the surface.

Requisites of Scheme of Soil Classification.—The classification of soil to be of the largest value should effect the accurate separation of materials with reference to all important inherent agricultural differences. This statement indicates the breadth of the point of view to be taken. It is that of the farmer—agriculture in its broadest sense. The classification should not be confined to any particular section of plant production. It should apply to flowers and forests as well as wheat and cotton. It should have a place for the roughest mountain region as well as for the most intensively tilled garden. To be less comprehensive is to invite arbitrary judgment and corresponding inaccuracy in the application of the scheme in the field. The distinctions with reference to plant growth and agricultural practise which should be made are differences in, first, chemical composition, including total content of plant food, amount of lime, amount and condition of the organic matter and the solubility of all these, including the presence of alkali salts; second, physical properties including texture, structure, color, moisture capacity, aeration and temperature; third, the climate under which these properties exist. These distinctions which will determine natural plant growth will also make sufficient provision for agricultural practise necessary to produce domestic crops.

The ideal result of the scheme of soil classificaton is to separate all soil material into types or individuals which are uniform in their agricultural value and distinct from every other type of soil. The soil type must be the unit and the primarily important separation in the scheme. Once the types are recognized they may be grouped according to any selected properties, irrespective of those involved in arriving at their identity.

Difficulties in the Field Separation of Soils.—Having pointed out the properties with reference to which soils should be classified, the next problem is to apply these in a systematic way in the field. Herein arise two kinds of difficulties: First, to classify soils directly by their properties for plant growth is impracticable. Take chemical composition, for example. To classify soils upon the basis of chemical analysis of samples of every acre or even every ten acres is impracticable because of the large amount of labor and time involved. To directly determine the moisture capacity, temperature and other essential factors of plant growth presents similar practical difficulties. The direct

method must, therefore, be set aside. The important crop-producing properties must be correlated with some group of characteristics of the soil which are more easily recognized and grouped, and by this means arrive at individual types of soil which have some measure of agricultural unity and value. The more perfect this correlation of properties the more satisfactory will be the result. The characteristics of the soil which have been most often selected for correlation with its crop-producing properties are the geological. Second. Herein lies the second group of difficulties, namely, in establishing the correct relation between crop-producing power and geological origin, and also in the accurate separation of soil material along geological lines, due to the complexity of the geological processes and materials involved. Attention should be directed here to a point often overlooked, namely, that the separation of soils along geological lines is secondary to their separation according to crop-producing power. The method is an incident to the result, however interesting it may be as a part of the science of geology. Much confusion in work has resulted from the failure to sense this distinction. The soil type is a geological element in the structure of the earth and as such is legitimately investigated by the geologist. Unfortunately, for agricultural purposes, the geologist has seldom carried his separations far enough, due probably to the fact that he has not had the agricultural point of view and, therefore, has not appreciated the kind of distinctions which are demanded for farming purposes. This may be termed the agronomic point of view.

Principles which have been used in the Classification of Soils.—The soil has been classified from many points of view. Emmons[1] studied the soils of New York between 1835 and 1840 and made somewhat extensive chemical analyses of the soils in the several regions into which the state was divided. This is probably the most extensive of the early surveys and combined the chemical composition with geological origin in arriving at the agricultural separation, a method generally employed by investigators working in this field. The physical properties of the material were also recognized as important, but these several factors were not correlated in any definite way. Owen and Peters[2] made a very comprehensive study of the chemical composition of the soils of Kentucky. Hilgard[3] has made the largest collection of the chemical analyses of soils available in America, in connection with the investigation of the cotton soils, and the soils are classified in the field and indicated on maps with reference to the native vegetation. The mode of formation and physical properties received consideration. Shaler[4] in an article published in 1891 called attention rather definitely to the relation between the processes of soil formation and the character of the material and pointed out correlated types of plant growth.

In foreign countries a number of men have studied the problem of the practical classification of soils and of these the Russians have been most successful. Dokou-

[1] Emmons, Ebenezer, "The Soils of New York. Natural History of New York," Agriculture, I., 207–360 (1843), 1846.

[2] Owen, D. D., Geological Survey, Kentucky, Annual Repts., 1855–1875. Peters, Robert, "Chemical Composition of Soils, Marls, Ores, etc., Chemical Analysis A," Pts. I., II., III., 1875–1888.

[3] Hilgard, E. W., "Cotton Production," 10th Census, V. and VI., 1880.

[4] Shaler, N. S., "Origin and Nature of Soils," 12th Ann. Rept. U. S. G. S., Pt. I., 219–345, 1890–91.

chayev with his pupils,[5] the most prominent of whom is Subertzev,[6] studied these questions for many years and arrived at what may be termed the most perfect and comprehensive scheme devised up to the present time. Theirs is a genetic system based upon climate, the formation of the soil, and the apparent properties. It was rather a statement of broad groups than the designation in systematic order of the factors, which give rise to agricultural differences in soils.

The credit for definitely correlating the physical properties of the soil with its agricultural belongs chiefly to Whitney[7] and his associates. By his work the textural properties of the soil, through their influence on the moisture capacity and general climate of the soil, were shown to have a very determinate effect on the crop-producing power of the soil. The adaptation of natural vegetation and of domestic plants largely reflects these properties. Grass is shown to be generally identified with fine-textured soils, corn with loams and truck and other special crops with rather light sandy loams.

The Federal Soil Survey.—In 1899, as chief of the United States Division of Soils, Whitney began the classification and mapping of soils in the field according to their evident agricultural value. At first the physical properties were used almost exclusively as the means of separation. This survey work expanded and many men were employed in the field. Gradually the scheme of classification expanded, under the lash of necessity, keeping always to the fore the agricultural significance of each separation. Over four hundred thousand square miles were surveyed up to the beginning of 1911, distributed more or less in every state in the union. These surveys have proved their value and more than anything else have demonstrated the necessity of such work as a basis in general agricultural investigations and in education. They have also exemplified the necessity of arriving at definite principles for the classification of soils which in their distribution have little relation to political boundaries. Following the lead of the federal government and as a supplement thereto, many of the states have taken up survey work, some independently and some in cooperation with the federal bureau. All this emphasizes the need for a common basis for work such as the committee on soil classification of the American Society of Agronomy is endeavoring to establish.

While of great value and proceeding upon a broad basis of separation of soil types designed to represent their chief agricultural differences, on the one hand, the work has not always been as accurate as it might have been and, on the other hand, it has not been properly understood or appreciated because the factors which are used in the classification of soils have never been accurately stated. Individual survey men have been left very largely to absorb the scheme of separation from contact with the older men in the bureau and to work it out for themselves from previous training and especially from experience in the field. Apparently the factors which are used in the separation of soils are not always recognized and the grouping of types is often not upon parallel lines or lines of equal significance. The properties which determine differences in value have not been clearly perceived. The corollary of inaccurate grouping is inaccurate boundaries of soil types. As an in-

[5] Tulaikov, N., "The Genetic Classification of Soils," *Jr. Agr. Sci.*, 3, No. 1, pp. 80–85, 1908.

[6] Subertzev, N., *Expt. Sta. Record*, 12, 704–712, 1900; 12, 807–818, 1901.

[7] Whitney, M., U. S. Weather Bureau Bul. 4. Also Buls. S. C. Agr. Expt. Sta., Md. Agr. Exp. Sta. and U. S. Bureau of Soils.

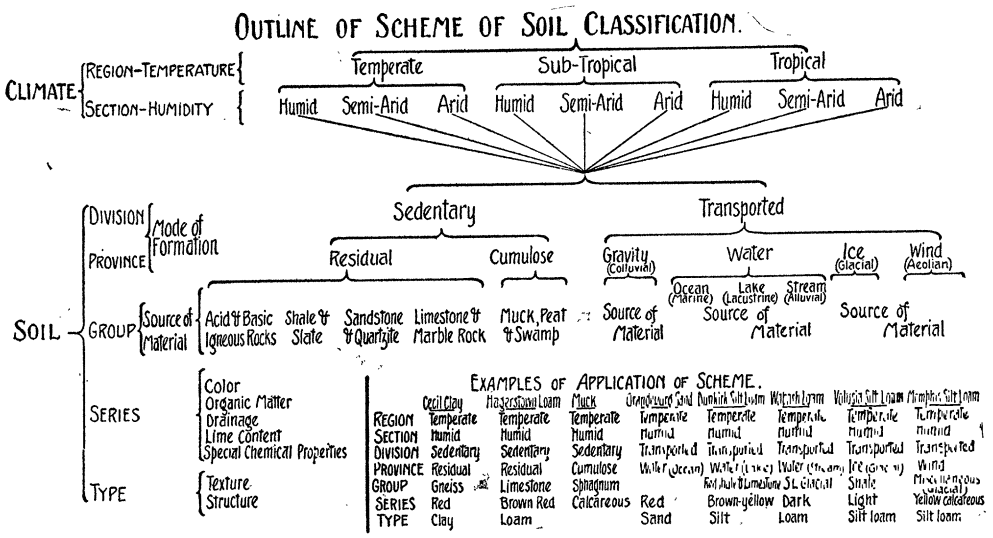
stance of the first inaccuracy the coastal plain is put on a par with the soils of glacial formation, however justified this may seem to be from the point of view of agricultural prominence. In the same line is the correlation of material occurring in the Ohio River bottom in Mason County, Kentucky, with the Norfolk series which is a part of the coastal plain. (Since changed.) The most serious errors in drawing the boundaries of individual types result from failure to appreciate the factors upon which the larger separations are made. These difficulties are pointed out, not to minimize the value of the work done, for they weigh lightly against the large and fundamental value of the surveys which have been completed, and which in the main are sound, but rather with the purpose to illustrate the importance of stating as clearly as possible the factors which are used in the practical classification of soils and the comparison of these with what may be termed an ideal scheme of classification. It is objected by some persons that it is not possible to devise a perfect scheme which is applicable under all conditions. The important point is rather that we now have a fair understanding of the primary factors which produce agricultural differences in soil and that the use of these in the classification, representation and study of soils is of great practical value. We shall attain nearer a perfect system as we accumulate more information on the subject. All of the elements of soil separation which are mentioned in the following pages have been employed in the work of the Bureau of Soils, but they have not been given equal or uniform value.

The most comprehensive review of the methods which have been used in the classification of soils is that by Coffey prepared as a thesis for the doctor's degree in George Washington University under the direction of Dr. George P. Merrill.

The aim of this paper is to organize the factors which have been used in the classification of soils and any others which appear to have a controlling influence on the agricultural value of soil into a scheme which shall point out the fundamental factors involved, and the relation of these factors to the distribution of soils in the field. The requisites and some of the limitations of such a scheme have been stated. It was noted that the crop-producing power of a soil is dependent upon its chemical and physical properties and the climate.

Statement of Plan of Classification.—The climate of a soil has two phases: First, the climate of the region in general, due to its geographic position. Second, the climatic conditions within the soil, due to the physical and chemical properties of the soil itself. Due to the latter two soils of different properties situated under the same general climatic conditions may present different climatic conditions to the plants growing upon them. The temperature and humidity of sand and clay may be very different, which is illustrated by the fact that one is termed an "early" soil and the other a "late" soil.

The physical and chemical properties of a soil are due to its mode of formation and the kind of materials used. The first include the time element or extent of operation of the processes and changes subsequent to the general formation of the material such as drainage, climate, etc. The second include the kind of rocks from which the soil material is derived and may be as diverse as the kinds of rock multiplied into the proportionate mixture of any combination of these. The scheme is, therefore, genetic and in its broader lines purely geological. The relation of these to agri-



cultural properties will be indicated as the scheme is developed.

Climate.—The broadest agricultural divisions in soil are due to climate. Although the soil material were the same (if that is possible), if it occurred under widely different conditions of climate it would have a different agricultural value and should be differentiated.

Climate consists of two primary elements. These are temperature and humidity, or precipitation.

I. *The Region. Temperature.*—We propose to term the groups of soils determined by temperature the *region* and the surface of the earth would be divided into belts or zones corresponding in general to these commonly made, and these may be multiplied if their agricultural diversity proves too great. The temperature has some influence upon the type of processes by which soils are formed and the changes which they are continually undergoing.

II. *The Section. Humidity.*—The groups determined by humidity we would term the section and the temperature zones would be subdivided according to the degree of aridity. In the United States three conventional groups have been recognized, namely, the humid, the semi-arid and the arid. Humidity has an especially marked effect upon the processes of soil formation and brings about distinct physical and chemical differences. In a general way in arid regions physical processes of the decay of rocks are relatively more prominent than chemical processes, resulting in soil which averages coarser in texture. Alkali or the excess of soluble salts is chiefly identified with aridity of climate. These are, therefore, broad distinctions in the properties of soil which should be recognized.

III. *The Province. Mode of Formation.*—The third great factor which determines the properties of a soil is the mode or process of formation. This includes all the processes and forces which have been operative in transforming rocks into soil and imparting to them distinctive physical and chemical characteristics. These are dynamic and, therefore, impress special properties upon the material handled. While several processes are usually operative on the same material, they are seldom equally prominent, and certain conventional groupings have been adopted by

geologists, especially those who have given much attention to soils, for example, G. P. Merrill.[8] These are (*a*) general weathering which gives rise to residual material. The type of weathering and the activity of the several forces will depend upon the kind of rock. (*b*) Decay acting upon organic material to give rise to cumulose deposits. It differs from weathering, since there is an actual building up of material due to biological activity and biological changes are dominant. These two groups taken together have been termed the *sedentary division,* since the material has not been appreciably moved. Where rocks are involved the soil is likely to rest on rock of the same kind as that from which the soil was formed. The physical as well as the chemical properties of the rock maintain much of their identity in residual soil—for example, quartz bands in gneiss rock and chert masses and other impurities in the different strata of limestone.

The remaining processes involve appreciable transportation of the material and have been grouped together as the *transported division.* Four great agencies of transportation are recognized.

(*c*) Gravity produces the slow sliding of material down rather steep slopes and in some instances it includes avalanche movement. The material is without organized structure and likely to be rather coarse and thin and of low agricultural value in both extent and adaptation.

(*d*) Water has been the great transporting and soil-forming agency. Many of the most famous agricultural portions of the earth owe their formation to water, notably the Nile Valley, the American coastal plain and the interior lake plains and stream valleys. It couples a wide range of transporting power with very decided sorting and in the deposit of the material produces stratification. Thereby nearly all of the areas of soil of distinct textural unity have been derived. Fine clay and clean, uniform sand are equally identified with the agency of water. Stratification implies differences in successive layers, and a shift in the direction or velocity of movement of the water when a material was being laid down may produce great variation in texture, structure and chemical composition. These principles of variation are so well understood that much explanation is unnecessary.

It is worth while to recognize three phases of action of water according to its breadth, extent of movement and to some degree its character. These are oceans (saline waters), lakes and streams. The depth, uniformity and chemical character of the soil formed under each of these influences are likely to be distinct. While water gathers rock material from many sources, each body is likely to have certain characteristics of its material due to the region drained.

(*e*) Ice in the form of glacial masses has been an extensive and important agency of soil-formation adjacent to the polar regions and in high mountains. Some of the most famous agricultural portions of the world, such as much of the Upper Mississippi River Valley owe their character to this agency. Here again peculiar chemical, physical and, to some extent, topographic features are imparted to the material handled. The kind of rock encountered, the rate and direction of movement of the ice and the minimum of chemical decay and leaching have determined the agricultural features of many regions formed by glacial ice. The soil conditions in New York State especially exemplify these distinctions.

Ice does not accomplish sorting or strati-

[8] Merrill, G. P., "Rocks, Rock-weathering and Soils," pp. 411, 1897, Macmillan Co., N. Y.

fication and is likely to produce a range in texture and a degree of compactness of the lower part of the soil section not found in soils formed in other ways. It is often difficult to distinguish between material deposited by pure ice action and that modified by glacial water due to the melting of the ice.

(*f*) Wind has not been so distinctively a soil-forming agency as water and ice, though it has very generally contributed to the result.[9] Like water it effects sorting and stratification, but the range in texture of material carried is very much more narrow, the type of stratification is different, and the material has a wider areal unity in chemical and physical properties. The most distinctive soil formations whose origin has been referred to the action of wind are sand dunes and loess. The former represents a large amount of material which has been rolled along the surface of the ground. It is usually a fine sand and shows sorting to the extent that very fine material is almost wholly removed. While the origin of loess has been referred to the settling of dust from the atmosphere, the American deposits exhibit properties which cause the adequacy of this theory to be questioned. In northern China, where this material was first recognized, its origin was attributed by Von Reichtofen to the agency of wind. At any rate it is a distinct material and seems more closely associated with this mode of formation than any other. The possible chemical and physical properties of wind-blown material entitle it to recognition in the scheme of classification.

IV. *The Group—Source of Material.*—The kind of rock from which a soil is formed is generally recognized to have a large influence on its chemical and physical properties. The mineral character of the rock and the extent of decay determines the texture of the soil. The composition of the rock influences both the composition and texture of the soil in a distinctive way. The same rock may be transformed into soil by several agencies and again the same agency may act on several kinds of rock. The product is likely to be equally diverse in its capacity to support plants. A large variety of rocks might be recognized as influencing the character of soils. The fact that soil has usually been derived from quite a variety of rocks, makes it necessary to keep the divisions here as broad as possible, since only such can be recognized with any degree of accuracy. These are rather large groups and in practise special distinctions are likely to be made on this basis. The primary groups to be recognized may be mentioned as acid and basic rocks of igneous origin, and with these the gneisses, schists and similar secondary rocks are likely to be included; shale and slate, sandstone and quartzite, limestone and marble. Plant remains constitute a separate and distinct class of material from which soil may be formed and the proportion of these which enters into any given formation may give distinctive character.

Often the mingling of material from several kinds of rock may impart peculiar character to the soils of a drainage system or a lobe of glacial ice. The red alluvial soils of the Red River drainage system owe their character largely to the red Permian formations of Oklahoma and Texas. The glacial soils of west central New York are largely dependent for their character upon the several shale, limestone and sandstone rock formations crossed by the ice in reaching that position. The line of movement of the material with reference to the gen-

[9] Free, E. E., "The Movement of Soil Material by the Wind," Bul. 68, Bureau of Soils, U. S. Dept. of Agriculture, pp. 272, 1911.

eral rock structure will largely determine the relation of the soil to any particular rock formation.

V. *The Series.*—The soil series is the most complex of the separations made in practise. Unlike the others, it does not rest upon a single character. Its separation requires the employment of a group of correlated characters. These are more intimate in their nature, more concerned with the material itself than the bases of the larger separations. Having applied those, the final grouping of types or units is determined first of all by

(*a*) *Color.*—Color as a physical property is not of great importance, but when considered in connection with the properties which are correlated with color it is of the greatest significance. Color is usually indicative of the proportion of organic matter, of the drainage, of the state of oxidation, of the proportion of lime carbonate and to a degree of the mineral composition of the soil.

(*b*) *Organic Matter.*—The proportion of organic matter is suggestive of the nitrogen content of the soil. It has a large influence on the availability of the mineral particles. It is indicative of the natural drainage, of the proportion of lime carbonate and of the activity and type of micro-organisms.

(*c*) *Lime Carbonate.*—The presence of a fair amount of this constituent has been pretty generally recognized as essential to a fertile soil.

(*d*) *The Total Plant Food Content of the Soil.*—While the average soil contains a relatively large quantity of the mineral plant food constituents, soils which are decidedly deficient in some one or more of these are sufficiently abundant to warrant the special consideration of this property. It does not necessarily involve general chemical analysis and may often be inferred from other properties. The solubility of the soil constituents, while seldom a distinctive series basis of separation, is often indicative of other characteristics of the soil and as alkali, especially, of the type of climate. These several elements will seldom, if ever, have equal value in deciding a separation. They can not well be applied independently in general field work. In some cases one, as color, may be dominant; in another drainage, and in still other separations it may be the lime content which will determine the grouping.

If one consider all soil series together without reference to their grouping according to the broader bases of classification, such as formation, etc., it will generally be observed that soil series are chiefly distinguished by chemical differences, that is, differences in composition and chemical form. Organic matter is suggestive of the nitrogen content, solubility, etc. The presence of lime is a matter of composition. Differences in rock material mean certain differences in composition. On the other hand, the last or unit separation of soils is based chiefly on physical properties—texture and structure. The series includes all material having the same characteristics, but varying in texture from the coarsest to the finest.

VI. *The Type. Texture and Structure.*—The fineness of the material of which a soil is composed is the most broadly influential of the physical properties of a soil. Through its influence on porosity, moisture relations, aeration, temperature, tillage properties, etc., it is probably the most dominant in deciding crop adaptation and agricultural value. The more distinct textures of clay, loam, silt and sand are generally recognized. These rest upon the proportion of particles of different sizes and a great variety of proportions may be recognized and given names. These are

being multiplied. A question requiring further consideration is the number of sizes of particles—separates—to be recognized and the limits of these. Several systems of groupings are now in use.[10] The finer the particles the greater is the influence of a given mass of them upon the character of the soil. Many more divisions should, therefore, be made in the fine material than in the coarse material. It is an open question whether, as survey work has been done in the United States, sufficient divisions have been made below the sand classes. Undoubtedly field separation of materials by hand examination is not likely to be more refined than is possible with the divisions now generally made. However, finer distinctions in the mechanical analysis of material smaller than 0.005 mm. may explain some variations in types of soil not otherwise recognized and these form the basis for more detailed study of individual types.

The structure of a soil as determined by the order of stratification and the thickness of the layers may also be the basis of type separation. This is independent of general structural differences due to the general mode of formation and the characters of the rock.

The soil type is the unit for soil study and should be as nearly alike in all parts as is possible. It is the most important grouping of material primarily because it does represent the chief physical differences in soils. The next most important grouping is the soil series and these two will be most generally identified with particular crop and agricultural interests in practise. This does not minimize the value of the larger separations, which, as has been suggested, are essential to reasonable accuracy in these last two groups.

[10] Briggs, L. J., et al., "The Mechanical Analysis of Soils," Bul. 24, Bureau of Soils, U. S. Dept. of Agr., 1904.

Of course the final test of a survey must be in the field man who applies these principles to a particular set of conditions. Owing to the intimate overlapping of several fields of natural science in this work it is evident that he should be a man of broad training, including especially geology and the principles of soil fertility, and he should have keen power of observation and correlation. Scarcely any experience or training which the field man may possess but finds use in the ideal soil-survey man.

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The British Association

A preliminary program has been issued for this year's meeting of the British Association, which, as already announced, is to take place at Dundee from September 4 to 11. The meeting will be the eighty-second of the series, the twelfth in Scotland, and the second in Dundee, the association having previously met in that city in 1867.

The opening meeting will be held in the Kinnaird Hall on Wednesday evening, September 4, when Professor E. A. Schäfer, F.R.S., will assume the presidency and deliver his inaugural address. In the same hall the first evening discourse will be delivered on Friday, September 6, by Professor W. H. Bragg, F.R.S., on "Radiations Old and New," and the second on Monday, September 9, by Professor A. Keith, on "The Antiquity of Man." The reception room and offices will be established in the Albert Institute, and a considerable proportion of the sections will have their meeting-rooms in the University College.

Arrangements have been made with the railway companies for the issue to members of return tickets at reduced fares, available for the period of the meeting and eight days after, and excursions during and after the meeting, for the purposes of scientific field-work, are expected to prove particularly important this year. The famous Alpine flora of Clova and Glenesk, the fossil fish beds of Dura Den, and the geology of the Stonehaven region and of the Western Highlands